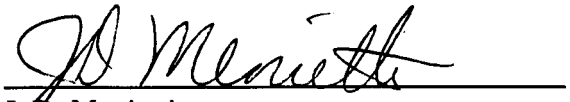
Title of Grant:	**Polar Plasma Wave Investigation Data Analysis in the Extended Mission**
Type of Report:	Annual Review (Summary of Research)
Principal Investigator:	Donald A. Gurnett
Period Covered by the Report:	1 January 2003 through 31 December 2003
Name and Address of the Recipient's Institution:	The University of Iowa Department of Physics and Astronomy Iowa City, IA 52242
Grant Number:	NAG5-11942
Signature:	Prepared by:



J. D. Menietti
Polar PWI Science Data Manager

D. A. Gurnett
Principal Investigator

1.0 Purpose

This Summary of Research is being submitted to NASA Goddard Space Flight Center in fulfillment of the annual reporting requirement under Grant NAG5-11942. This summary includes some details of a few exemplary accomplishments of the Polar Plasma Wave Investigation known during the period January 1, 2003, to December 2003, and a list of publications and pending publications during that same period. The website link to the Polar/PWI publications is as follows:

http://www-pw.physics.uiowa.edu/plasma-wave/istp/polar/publications.html

2.0 Summary of Exemplary Accomplishments

ELF/VLF plasma waves in the low latitude boundary layer
B. T. Tsurutani, G. S. Lakhina, L. Zhang, J. S. Pickett, and Y. Kasahara

Abstract. The low latitude boundary layer (LLBL) is a region where solar wind momentum and energy is transferred to the magnetosphere. Enhanced "broadband" electric plasma waves from < 5 Hz to 10^5 Hz and magnetic waves from < 5 Hz to the electron cyclotron frequency are characteristic of the LLBL. Analyses of Polar plasma waves show that these "broadband" waves are actually discrete electrostatic and electromagnetic modes as well as solitary bipolar pulses (electron holes). It is noted that all wave modes can be generated by ~ 100 eV to ~ 10 keV auroral electrons and protons. We will review wave-particle interactions, with focus on cross-diffusion rates and the contributions of such interactions toward the formation of the boundary layer. In summary, we will present a scenario where the global solar wind-magnetosphere interaction is responsible for the auroral zone particle beams, and hence for the generation of plasma waves and the formation of the boundary layer. It is speculated that all planetary magnetospheres will have boundary layers and they will be characterized by similar currents and plasma wave modes.

Frequency-time spectra of magnetospherically reflecting whistlers in the plasmasphere
J. Bortnik, U. S. Inan, and T. F. Bell

Abstract. We present a numerical method of simulating at any location in the magnetosphere, the observed frequency versus time (f-t) spectrogram resulting from a lightning strike at any given latitude on Earth. Using a two-dimensional ray tracing code, we calculate the trajectories of 5330 whistler rays that effectively sample the lightning strike's frequency spectrum and latitudinal spread about the source and then use these so-called "sample rays" to create ~ 120 million interpolated rays, each weighted with a measure of energy according to its frequency and injection latitude. This energy is progressively attenuated along the ray's trajectory using a Landau damping calculation with realistic suprathermal electron fluxes. A detection area is

defined in the plasmasphere, and rays that cross this area are used to construct the f-t spectrogram representative of what would be observed on a satellite located in that region. We investigate the role that the lightning source latitude, observation location, and plasmaspheric electron density structures have on the appearance of the simulated f-t spectrograms and show that all three parameters exhibit distinct and well-defined effects. In particular, we focus on plasmaspheric electron density structures and explain the connection between these structures and the appearance of specific observed features in the spectrograms. Using this analysis, it may be possible to crudely infer certain features of the source and plasmasphere from observed magnetospherically reflecting whistler spectrograms.

High resolution observations of continuum radiation in the near-source region
J. D. Menietti, O. Santolik, J. S. Pickett, and D. A. Gurnett

Abstract. The Polar spacecraft has identified near-source regions of continuum emission in the plasmapause and outer plasmasphere. As in the case of kilometric continuum (KC), near-source regions of continuum emission often display a high resolution fine structure of closely-spaced bands of emission. The separation of the bands is much less than the local gyrofrequency. This suggests that the source is associated with density structures, and perhaps the result of trapped eigenmodes. These results imply further that continuum emission is the low-frequency manifestation of kilometric continuum emission.

Polar observations of plasma waves in and near the dayside magnetopause/magnetosheath
J. D. Menietti, J. S. Pickett, George Hospodarsky, D. A. Gurnett, and J. D. Scudder

Abstract. The plasma wave instrument (PWI) on board the Polar spacecraft made numerous passages of the dayside magnetopause and several probable encounters with the magnetosheath during the years 1996 and 1997. During periods of relatively high density the PWI antenna-receiver system is coupled to the plasma and oscillates. The oscillations have been shown [cf. Beghin and Kolesnikova, 1997; 1998] to be indicative of periods of higher plasma density and plasma flows, possibly associated with magnetic reconnection. We have studied the plasma waves observed on three distinct magnetopause passes distinguished by the presence of these oscillations of the PWI receivers, and we report on the data obtained near but not during the times of the oscillations. Sweep-frequency receiver and high resolution waveform data for some of these times is presented. The plasma wave measurements on each of the passes is characterized by turbulence. The most stable waves are whistler mode emissions typically of several hundred hertz that are seen intermittently in these regions. The data indicate the presence of impulsive solitary-like wave structures with strong electric fields both parallel and perpendicular to the magnetic field. These impulsive waves, which have been said to be associated with electron beams, may contribute to significant ion and electron heating in these regions. Electrostatic electron cyclotron waves are observed occasionally in these regions. These waves have been observed in the past in the cusp, polar magnetosphere, and auroral

regions and therefore may represent excursions into the cusp, but also indicate the presence of low-energy electron beams and the highest occurrence rate of solitary wave structures. Of significance also is the presence of turbulent emissions with frequencies typically near the lower hybrid frequency seen throughout the magnetopause and particularly near regions of large decrease in the local magnetic field.

3.0 Future and On-going Research at the University of Iowa

During the 2004 calendar year we will attempt to complete a number of open PWI science efforts. These include at least the following:

Menietti, J.D., I. W. Christopher, B. Giles, and D. A. Gurnett, The role of solitary waves in transverse heating of auroral ions.

Menietti, J. D., J. S. Pickett, G. B. Hospodarsky, D. A. Gurnett, and J. D. Scudder, Polar observations of plasma waves in and near the dayside magnetopause/magnetosheath, submitted to *Planet. Space Sci.*, 2003.

Menietti, J. D., O. Santolik, J. S. Pickett, and D. A. Gurnett, High resolution observations of continuum radiation, submitted to Special Issue of *Planet. Space Sci.*, 2003.

Santolik, O., J. D. Menietti, J. S. Pickett, D. A. Gurnett, and J. D. Scudder, Magnetic component of waves near the proton cyclotron frequency and its harmonics,

4.0 Future and On-going Research at Stanford University STAR Laboratory

During the 2004 calendar year we will attempt to complete a number of open PWI science efforts. These include at least the following:

PWI and CEPAD/IES observations on Polar of intense VLF chorus emissions and energetic electrons near the magnetic equator, T. F. Bell, U. S. Inan, R. A. Helliwell, et al.

Anisotropic energetic electron velocity distributions in the plasmasphere and the amplification of whistler mode waves, T. F. Bell, U. S. Inan, and J. D. Scudder.

5.0 Publications in 2003

A list of all of the publications that resulted from work carried out partially or wholly under the subject grant during the reporting period is as follows:

Denton, R. E., J. Goldstein, J. D. Menietti, S. L. Young, Electron density in the magnetosphere, submitted to *J. Geophys. Res.*, 2003.

Menietti, J. D., R. R. Anderson, J. S. Pickett, D. A. Gurnett, and H. Matsumoto, Near-source and remote observations of kilometric continuum radiation from multi-spacecraft observations, *J. Geophys. Res., 108*, 1393, doi:10.1029/2003JA009826, 2003.

Tsurutani, B. T., G. S. Lakhina, L. Zhang, J. S. Pickett, and Y. Kasahara, ELF/VLF plasma waves in the Low Latitude Boundary Layer, in *Earth's Low-Latitude Boundary Layer*, edited by P. Newell and T. Onsager, Amer. Geophys. Un. Press, *133*, p. 189, 2003.

Tsurutani, B. T., B. Dasgupta, J. K. Arballo, G. S. Lakhina and J. S. Pickett, Magnetic field turbulence, electron heating, magnetic holes, proton cyclotron waves, and the onset of bipolar pulses (electron hole) events: A possible unifying scenario, *Nonlinear Proc. in Geophys., 10*, 27, 2003.

Mjolhus, E., B. T. Tsurutani, and J. Buechner, The Tromso nonlinear wave workshop, *Nonlinear Proc. in Geophys., 10*, 3, 2003.

Lakhina, G. S., B. T. Tsurutani, S. V. Singh and R. V. Reddy, Some theoretical models for solitary structures of boundary layer waves, *Nonlinear Proc. in Geophys., 10*, 65, 2003.

Lakhina, G. S., B. T. Tsurutani and J. S. Pickett, Broadband plasma waves in the magnetopause and plasma sheet boundary layers, *The Reviews of Radio Science 1999-2002*, edited by W. R. Stone, URSI, IEEE Press, Wiley, N.Y., Chapter 30, 721, 2003.

Bortnik, J., U. S. Inan, and T. F. Bell, frequency-time spectra of magnetospherically reflecting whistlers in the plasmasphere, *J. Geophys. Res., 108, A1*, 1030, doi:10.1029/ 2002JA009387, January 2003.

W. L. Imhof, R. R. Anderson, M. Walt, J. D. Hawley, S. M. Petrinec, J. Mobilia, and H. Matsumoto, The dependence of AKR production on the intensity and energy spectra of auroral bremsstrahlung, *J. Geophys. Res., 108, A3*, 1099, doi:10.1029/2002JA009274, March 2003.

Lakhina, G. S., B. T. Tsurutani, S. V. Singh, and R. V. Reddy, Some Theoretical models for solitary structures of boundary layer waves, in *Nonlinear Processes in Geophysics, 10*, No. 1/2, 65-73, March 2003.

Chang, S. W, J. D. Scudder, S. A. Fuselier, J. Fennell, K. J. Trattner, J. S. Pickett, H. E. Spence, J. D. Menietti, W. K. Peterson, R. P. Lepping, and R. Friedel, Correction to "Cusp energetic ions: A bow shock source, *Geophys Res. Lett.*, 30, 1149, doi:10.1029/ 2002GL016613, March 2003.

Tsurutani, B. T., G. S. Lakhina, L. Zhang, J. S. Pickett, and Y. Kasahara, ELF/VLF Plasma Waves in the Low Latitude Boundary Layer, in *Earth's Low-Latitude Boundary Layers, Geophysical Monograph 133*, eds. P. Newell and T. Onsager, pp. 189-203, doi:10.1029/133GM19, American Geophysical Union, Washington, DC, March 2003.

Lakhina, G. S., B. T. Tsurutani, and J. S. Pickett, cross-field diffusion at the magnetopause: role of boundary layer Waves, in *Very Low Frequency (VLF) Phenomena*, ed. by A. R. W. Hughes, C. Ferencz, and A. K. Gwal, pp. 151-163, Narosa Publishing House, New Delhi, March 2003.

Bortnik, J., U. S. Inan, and T. F. Bell, Energy distribution and lifetime of magnetospherically reflecting whistlers in the plasmasphere, *J. Geophys. Res.*, 108, A5, 1199, doi:10.1029/2002JA009316, May 2003.

Inan U. S., T. F. Bell, J. Bortnik, Controlled precipitation of radiation belt electrons, *J. Geophys. Res., Vol. 108, No. A5*, 10.1029/2002JA009580, May 2003

THESIS:

Bortnik J., Precipitation of radiation belt electrons by lightning-generated magnetospherically reflecting whistler waves, Stanford University, Palo Alto, CA 94305

6.0 Publications - In Press:

Santolik, O., J. S. Pickett, and D. A. Gurnett, Electromagnetic Auroral waves near the proton gyrofrequency and its lowest harmonics, *J. Geophys. Res.*, in press, 2002.

Savin, S., L. Zelenyi, S. Romonov, I. Sandahl, J. Pickett, E. Amata, L. Avanov, J. Blecki, E. Budnik, J. Buechner, C. Cattell, G. Consolini, J. Fedder, S. Fuselier, H. Kawano, S. Klimov, V. Korepanov, D. Lagoutte, F. Marcucci, M. Mogilevsky, Z. Nemecek, B. Nikutowski, M. Nozdrachev, M. Parrot, J. L. Rauch, V. Romanov, T. Romantsova, C. T. Russell, J. Safrankova, J. A. Sauvaud, A. Skalsky, V. Smirnov, K. Stasiewicz, J. G. Trotignon, Yu. Yermolaev, Magnetosheath-cusp interface, *Ann. Geophys.*, in press, 2003.

Murata, K. T., W. Kurth, K. Hashimoto, and H. Matsumoto, Occultations of auroral kilometric radiation in the vicinity of the Earth, in Proceedings of the COSPAR Colloquium on *Frontiers of Magnetospheric Plasma Physics*, in press, 2003.

7.0 Publications - Submitted

Cummer, S. A., J. L. Green, B. W. Reinisch, S. F. Fung, M. L. Kaiser, R. L. Mutel, J. S. Pickett, I. W. Christopher, and D. A. Gurnett, Advances in magnetospheric radio wave analysis and tomography, *Adv. Space Res.*, submitted, 2003.

Cao, X., J. D. Scudder, F. S. Mozer, J. D. Menietti, and C. T. Russell, Thermal properties of very cold electrons in the magnetosphere including the high latitude plasmasphere, *J. Geophys. Res.*, submitted, 2003.

Anderson, R. R., H. Matsumoto, K. Hashimoto, H. Kojima, Y. Kasaba, M. L. Kaiser, J.-L. Bougeret, J.-L. Steinberg, and G. Rostoker, Geotail, Polar, and Wind observations of auroral kilometric radiation, *Frontiers of Magnetospheric Plasma Physics*, submitted, February 2003.

Lakhina, G. S. B.T. Tsurutani and J. S. Pickett, Broadband plasma waves in the magnetopause and plasma sheet boundary layers, submitted to *Nonlinear Proc. Geophys.* 2003.

Menietti, J. D., J. S. Pickett, G. B. Hospodarsky, D. A. Gurnett, and J. D. Scudder, Polar observations of plasma waves in and near the dayside magnetopause/magnetosheath, submitted to *Planet. Space Sci.*, 2003.

Menietti, J. D., O. Santolik, J. S. Pickett, and D. A. Gurnett, High resolution observations of continuum radiation, submitted to Special Issue of *Planet. Space Sci.*, 2003.

8.0 Publications -In Preparation:

Bell, T. F., U. S. Inan, R. A. Helliwell, and M. Carter, PWI and CEPAD/IES observations on polar of intense VLF chorus emissions and energetic electrons near the magnetic equator, *J. Geophys. Res.*, in preparation, May 2003.

Bell, T. F., U. S. Inan, and J. D. Scudder, Anisotropic energetic electron velocity distributions in the plasmasphere and the amplification of whistler mode waves, *J. Geophys. Res.*, in preparation, May 2003.

Olsson, A., P. Janhunen, M. Mogilevsky, J. Hanasz, S. Perraut, J. D. Menietti, and G. K. Parks, Observational study of generation mechanism of substorm-associated low-frequency AKR emissions, in preparation, 2003.

9.0 Public Outreach

A list of the public outreach activities carried out during the reporting period of the subject grant in which the Polar mission and Polar PWI are listed on the Polar/PWI website given above.